MAT-91-02

The Effectiveness of Calcium Magnesium Acetate De-icer under Severe Operating Conditions, Winter 1989/90 and 1990/91

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Abstract: A field study was undertaken during two winters to evaluate the effectiveness of calcium magnesium acetate (CMA) as a highway de-icer on a two-lane rural highway in southern Ontario. The test site was subject to heavy snowfall, strong winds and cold temperatures.

CMA and sand mixed with CMA were used on one section of the highway. Salt and sand mixed with salt were applied in accordance with standard Ministry procedures, to an adjacent section of the same highway. The timing and rates of material application, and resulting changes in road surface conditions, were monitored closely by field personnel and automatic recording devices.

CMA was effective in conditions of light snowfall and air temperatures warmer than -6°C. The proportion of applications which resulted in improved conditions decreased substantially at temperatures colder than -6°C. Using a criterion of up to two hours to produce an improvement in pavement conditions, CMA had similar effectiveness to salt during 74% of storm events in 1989/90 and 80% of events in 1990/91. If a criterion of 30 minutes was applied, as is more usual in Ontario, the degree of effectiveness was reduced to appoximately 50%. Effectiveness was increased slightly by prewetting the CMA with a solution of CMA. The liquid reduced the amount of de-icer blowing off the road under dry, cold or windy conditions, and also increased the rate of ice melting.

CMA was stored in a steel silo, and loaded using an electric auger. This system prevented the loss of CMA pellets or dust during loading operations. Material was spread using a conventional salt spreader with appropriate gate adjustments. It was dropped through the salt chute onto a slowly rotating spinner to effect distribution part way across the road. The CMA spreading equipment showed no corrosion at the end of either season.

Comments: This report adds to the work described in MAT-88-06, which describes the results of field trials using CMA under less severe operating conditions.

Key Words: calcium magnesium acetate, CMA, salt, sodium chloride, de-icing chemicals, snow and ice control, winter maintenance

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1/ Introduction

The Ontario Ministry of Transportation (MTO) is responsible for clearing snow and ice from highways under its jurisdiction. This is carried out by plowing, sometimes combined with chemical de-icing, after snow or ice has accumulated to specified depths [1]. Rock salt (sodium chloride) is used to weaken the chemical bond between packed snow or ice and the pavement surface, or to melt sticking snow. Salt is effective under most of the winter weather conditions experienced in the province, and is inexpensive relative to other available de-icers.

The use of sodium chloride as a de-icer has a number of adverse environmental effects including: increasing the rate of corrosion of steel in automobiles and highway infrastructure materials, damaging sensitive vegetation along the roadside, and contributing salt to highway runoff water. MTO has responded by minimizing the quantities of salt used and by searching for effective and economic alternatives.

Calcium magnesium acetate (CMA) was identified in the late 1970s as a possible alternative to salt [2]. Unlike salt, CMA does not promote the corrosion reaction in steel or have a significant effect on roadside plants or highway runoff [2]. It was tested by MTO near Beamsville, Ontario [3] and has also been tested by the Province of Alberta, municipalities and several U.S. states [4].

CMA provides an equivalent number of ions in solution and has an effectiveness theoretically equivalent to salt when applied at a mass of 1.7 to 1 of salt. However, application ratios lower than 1.7 to 1 have been used in most field trials, as have the total quantities used over the winter [5]. Application rates of 182 to 221 kg/2-lane km (1.4 to 1.7 times the standard salt application) were used at Beamsville, and no differences in effectiveness due to the application rate were observed [3].

CMA was shown, in Ontario and elsewhere, to have de-icing capabilities similar to salt at temperatures near 0°C. It became noticeably less effective at colder temperatures (ranging from -5 to -9°C), or where snowpack was present, unless de-icing was assisted by the action of vehicle tires [4]. The Ontario trials were located in the southwest part of the province, in test conditions of relatively warm air temperatures, light snow and heavy traffic, which did not allow an assessment of the performance of CMA under more severe winter conditions, typical elsewhere in the Province.

2/ Objectives

The primary objective of this study was to determine whether CMA could be used as the sole de-icer in conditions of cold temperatures, heavy snow and light traffic. Such conditions are typical of rural highways in central, eastern and northern Ontario.

A secondary objective was to develop and test methods of handling CMA which would minimize spillage or other loss of this expensive material.

3/ Methodology

3.1/ Test Criteria

The conditions under which MTO standards can be met using CMA were identified by using it in the place of salt, in the winter maintenance program at one patrol yard near Owen Sound, Ontario. Its effectiveness as a de-icer was measured in the test area under a variety of weather and traffic conditions. CMA was compared with salt using several criteria, including: overall quantities used; storage, handling and spreading characteristics; time required to initiate de-icing; drying and persistence of effects; skid resistance of de-icer solution; and effect on vehicles.

3.2/ Test Sites and Procedure

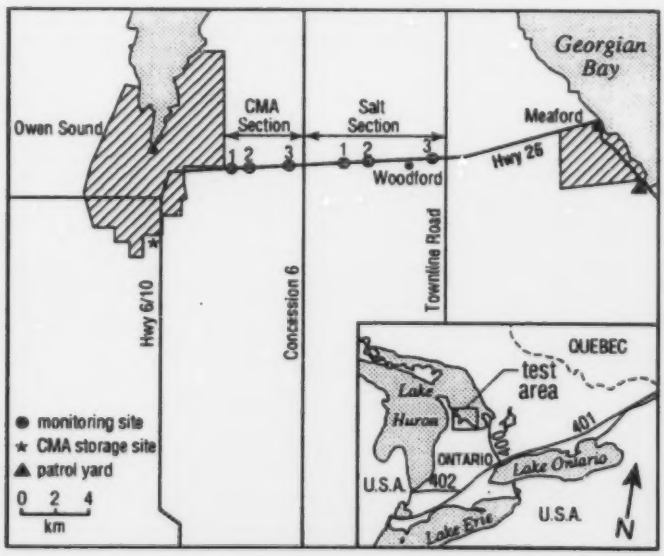
The trials were conducted on Highway 26 between the eastern limit of Owen Sound and the western limit of Meaford. Highway 26 is a 2-lane road with a bituminous wearing surface and Winter Average Daily Traffic (W.A.D.T.) of 3400 vehicles. The test area is located to the east of Lake Huron and south of Georgian Bay, and is subject to frequent snow squalls and prolonged periods of cold night-time temperatures. The mean winter snowfall is 2.8 metres, with an average of 24 days per year experiencing blowing snow, average daily maximum temperatures in January and February of -2.4°C and average daily minimum temperatures of -10°C [6, 7, 8].

CMA was tested during the winter seasons of 1989/90 and 1990/91 by applying it to the road surface and monitoring the effectiveness of ice melting, disbonding and other processes. The CMA was from the same commercial supplier as used at Beamsville.

In each year of the trials, two sections of Highway 26 were designated for testing: the "CMA test section" and the "salt test section". Only the specified de-icer was applied, either neat or mixed with sand, to its designated section. Winter sand mixed with the respective de-icer was also applied in each section, as necessary. The test sections used during 1989/90 and 1990/91 are shown in Figures 1 and 2.

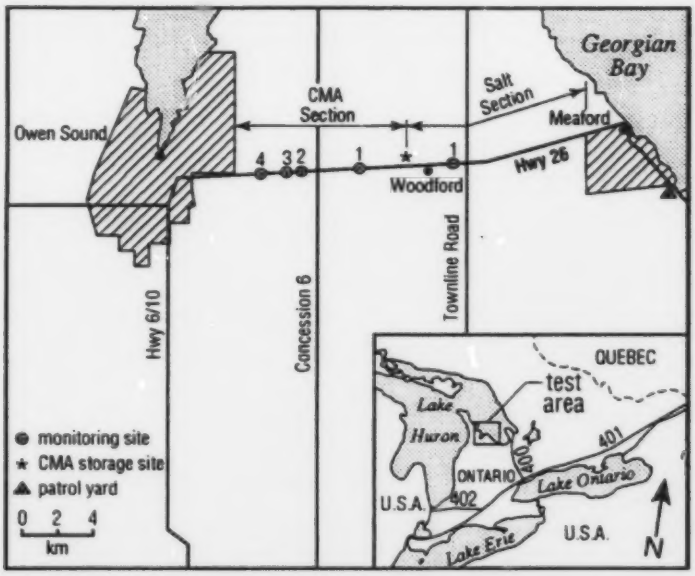
Within each section, observations and measurements were made at specific test sites. These test sites were selected because they represented the surrounding section of highway, and they experienced a range of road weather conditions, the conditions were comparable in both sections, and the possibility of tracking de-icer solution from the adjacent section was minimal. The test sites are shown in Figures 1 and 2, and the conditions represented are defined in Table 1.

CMA was stored at a Ministry yard in the test area and was applied to the test section all winter, as though it was the only de-icing chemical available. Salt was applied to adjacent sections of the highway in accordance with Ministry standards. Records were made of the times, methods, rates and quantities of each application, and also of the times at which each lane was plowed. Traffic volume and weather conditions were also measured. Other data were collected to assess the effectiveness of CMA as a de-icer, as a disbonding agent and in preventing freezing of winter sand stockpiles.



CMA	*#1.*	*Bothwell's Creek, 2.1 km east of 14th Ave. S.E.*
	2	*"Conservation Authority" sign at truck climbing lane, 2.8 km east of 14th Ave. S.E.*
	3	*"Roger Lamont" mailbox, 5.1 km east of 14th Ave. S.E.*
Salt	*#1.*	*"G. Schwillinger" mailbox, 2.2 km east of Sydenham Concession 6*
	2	*"G. Snider" mailbox, 3.4 km east of Sydenham Concession 6*
	3	*"Woodford" town sign (W.B.), 7.2 km east of Sydenham Concession 6*

Figure 1/ 1989/90 test sites



CMA #1. Incline of Irish Block Hill, west of Concession 4
2. Hillcrest east of Owen Sound Municipal Airport
3. West end of Golf Club parking lot
4. Bothwell's Curve
Salt #1. 100 m east of Woodford Patrol Yard laneway

Figure 2/ 1990/91 test sites

Table 1/ Test site characteristics

CMA section 1989/90

1) level, open site with moderate snowfall and heavy drifting
2) inclined, forested site with passing lane, moderate snowfall and light drifting
3) level, open site with moderate snowfall and heavy drifting

Salt section 1989/90

1) level, open site with moderate snowfall and heavy drifting
2) level, open site with moderate snowfall and heavy drifting
3) inclined, forested site with moderate snowfall and light drifting

CMA section 1990/91

1) inclined, forested site with moderate snowfall and light drifting
2) level, partially forested site with moderate snowfall and moderate drifting
3) level, open site with moderate snowfall and moderate to heavy drifting
4) level, open site with moderate snowfall and heavy drifting

Salt section 1990/91

1) level, partially forested site with moderate snowfall and moderate drifting

3.3/ Storage and Handling

De-icer storage and handling includes transferring the de-icing material from the supplier's delivery truck into temporary storage at a Ministry patrol yard, and either transferring it from storage into a spreader truck, or mixing it with winter sand to prevent stockpile freezing.

CMA was stored and handled during the Beamsville trials using equipment designed for salt. It was dumped from delivery trucks onto a paved apron outside a salt shed, and moved from the shed into spreaders or mixed into winter sand using a front-end loader. Several problems were encountered, including: spillage of CMA which coated the wet loading apron in a sticky film, dust during loading operations, and determination of the optimum ratio of CMA to salt in the sand stockpile.

During the Owen Sound trials, CMA was stored in a 90 cubic metre steel bin similar to the type normally used to store grain (Figure 3). The bin was located at a sub-yard at Owen Sound during the 1989/90 trials (Figure 1) and at a sub-yard near Woodford during the 1990/91 trials (Figure 2). Material was transferred from highway transport trucks into the bin, and from the bin into spreader trucks using electrically driven augers (Figure 4). Three lever-actuated indicating devices were installed at different heights in the bin wall to display the quantity of CMA remaining in storage.

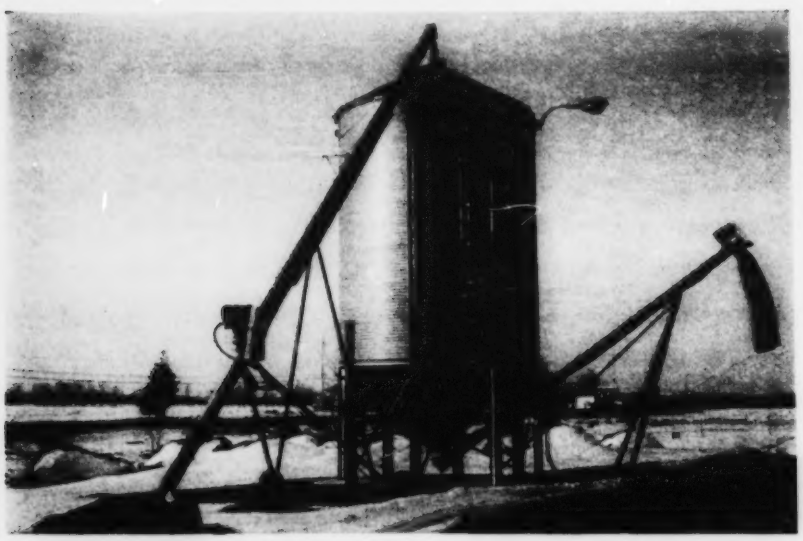


Figure 3/ CMA storage bin

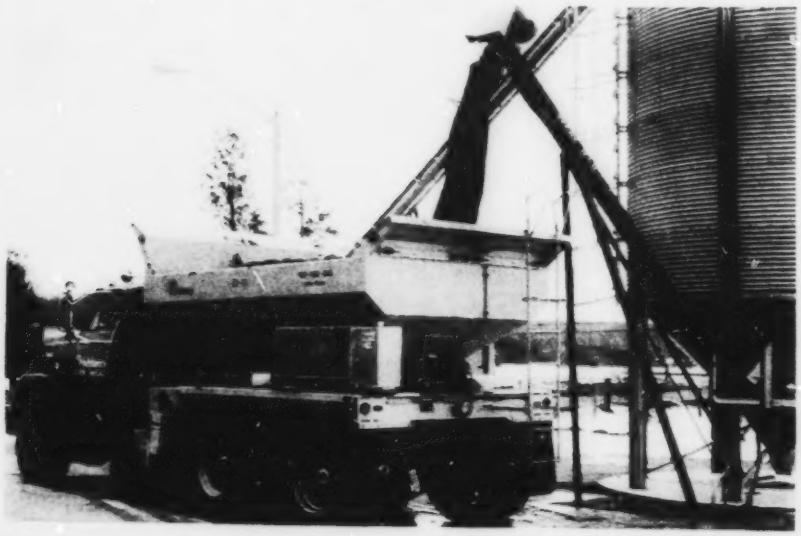


Figure 4/ CMA loading procedure

Material used on the salt section of the highway was stored in a conventional salt shed at a patrol yard at Meaford (Figures 1, 2) and transferred into the spreader truck with a front-end loader.

Winter sand used on the CMA section was stored in a sand dome adjacent to the CMA storage bin. Sand used on the salt section was stored in a dome at Meaford.

The effectiveness of the storage system was documented qualitatively by discussion with patrol personnel and by observation of the handling operations. Samples of the CMA were taken before loading into the storage bin and after loading into the spreader truck, to determine whether the physical and mechanical properties changed during storage and handling.

De-icers are added to sand stockpiles to prevent moisture in the stockpiles from freezing during the winter. The standard ratio of 5% sand by mass was used in the salt test sections. A ratio of 5% CMA was used in the CMA test sections during 1989/90. The ratio was lowered to 2% in 1990/91, because 5% appeared to dry the sand, resulting in excessive blow-off.

The effectiveness of CMA in preventing freezing of sand stockpiles was observed qualitatively, and samples were taken from the stockpiles to measure changes in bulk water content through one winter.

An additional handling process, not a normal part of Ministry practice, was included in the 1990/91 trials: the application of liquid CMA as a pre-wetting agent both on dry CMA and on winter sand. The purpose of pre-wetting was to determine whether excessive blow-off, observed in the first year of the trials, could be reduced. Operation of the spray system used to apply the liquid was evaluated qualitatively.

3.4/ Application Rate and Method

Key measures of the effectiveness of a de-icer is the quantity of the material and the time required to effect ice melting or disbonding under given weather and traffic conditions. Therefore, detailed records were made of the timing, spread rate, and total quantities of CMA, salt and sand applied at each test site during each storm.

CMA and CMA/sand were applied using a 3.5 cubic metre salt spreader in 1989/90 and a 6.0 cubic metre spreader in 1990/91. Both were equipped with a belt feeder, front chute and spinner. The spreaders were calibrated before each winter, and the calibrations were verified by dividing the volume loaded in the spreader by distance covered. Predetermined quantities of CMA were loaded into the spreader truck by timing the loading auger and verifying the volume against markers inside the spreader box. The loading rate was approximately 500 kg/min. Spreaders of the same design to those used in the CMA section were used in the salt section.

CMA was applied by dropping it over a fixed or slowly rotating spinner to effect spreading across the road surface. This method was used instead of the conventional method of de-icer application, a windrow down the centreline, because previous trials showed that CMA did not dissolve and spread as a solution. Instead it formed a slush which remained relatively stationary where the pellets were applied.

The timing and rate of application differed in the two years of testing. An application rate of 195 kg/ 2-lane km, or 1.5 times the standard salt application rate, was used in 1989/90.

The first applications of CMA and salt in each storm were made at the same time. This was to permit direct comparisons of the de-icing effectiveness of CMA and salt. Subsequent applications during a storm were made independently as warranted by road conditions. However, road weather conditions were not sufficiently similar in the salt and CMA test sections to warrant direct comparison, and procedures were changed after the first year of trials.

In 1990/91, the timing of CMA applications was scheduled so as to optimize effectiveness, and was not related to the timing of material application in the salt section. The application rate was also

adjusted by the patrol supervisor between 195 and 247 kg/2-lane km, depending on road and weather conditions.

Several of the 1990/91 applications included the use of a 25% solution of CMA in water, which was sprayed on the CMA pellets and winter sand as a pre-wetting agent. The pre-wetting apparatus consisted of a commercial weed sprayer mounted on the spreader as shown in Figure 5. The spray apparatus incorporated a heater and anti-freeze system to prevent freezing and maintain a low viscosity of the solution during storage. A thermometrically-controlled, 110 volt electric heater was installed in the liquid storage reservoir, and maintained the liquid temperature above freezing while the spreader truck was parked at the CMA storage yard. Alcohol-based anti-freeze was circulated by an electric pump to prevent the de-icer solution from freezing in the hydraulic lines while the truck was parked. The anti-freeze was transferred into a separate storage reservoir before the spray system was operated. The liquid was applied at a pressure of 224 kPa, through a flat tip nozzle which sprayed a fine mist onto the CMA pellets or sand grains on the spinner. The resulting application rate was 1.9 L/min, or approximately 3.75 L/2-lane km, depending on vehicle speed. The sprayer could be turned on and off by the truck operator while under way.

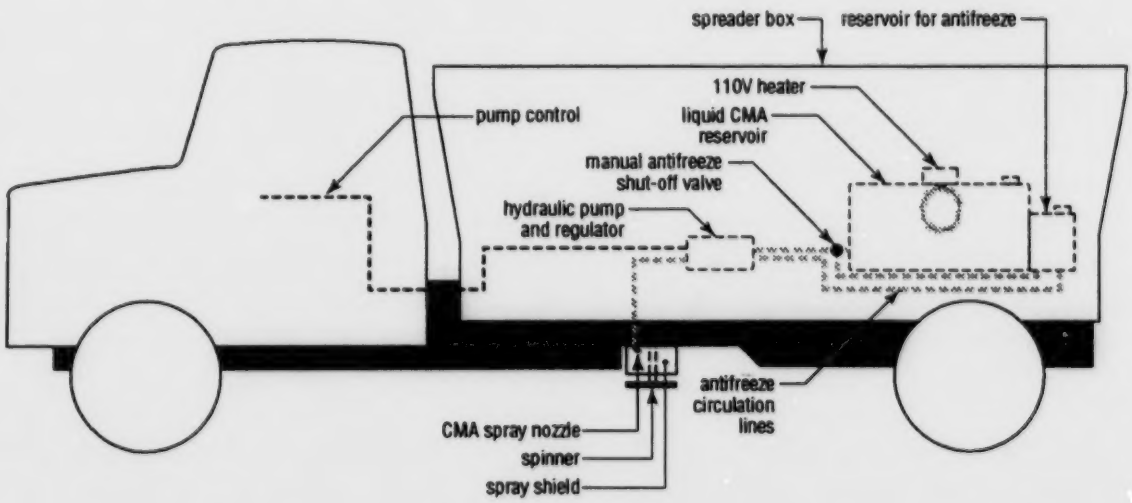


Figure 5/ CMA spreader truck with liquid spray apparatus

The timing and application rates of all materials were recorded on log sheets by vehicle operators, test monitors and patrol supervisory personnel. The spreader operator recorded the application rate and the time as the spreader passed each test site; plow operators recorded the time as the plow passed each test site; and the de-icing monitoring personnel recorded the times as the spreaders or plows passed the occupied test sites. The patrol supervisor also maintained records of the time of each spreader or plow call-out and the amount of material applied. These four independent sources ensured that the data on material spreading and plowing were recorded accurately and completely. In addition, spreader and plow times were checked against a time-lapse video record at Site 3 for the 1990/91 trials. Samples of the data sheets used to record the spreader and plow operations are shown in Appendix A.

3.5/ Spread Width and Blow-off

As noted previously, CMA and CMA/sand were observed in the first year of trials at Owen Sound, and elsewhere, to roll or blow off the road excessively as compared with salt and salt/sand. Blow-off occurs when de-icer pellets which are bouncing along the road after falling from the spreader or spinner are entrained by air currents perpendicular to the road and are carried off the edge of the pavement. The air currents may result from ambient wind or from passing vehicles. Under very windy and dry conditions, stationary de-icer pellets may be entrained and carried off the road. Tests were included in 1990/91 to determine whether the rate of blow-off could be reduced by pre-wetting the material with liquid CMA, as it was applied to the road.

Spreading characteristics were observed in a qualitative manner by test personnel as the spreader truck passed occupied stations, and by videotaping the spreading operations from the trailing vehicle. Blow-off was documented at observation sites by mapping the spread width and density under different wind and pavement wetness conditions.

3.6/ Effectiveness of Ice Melting and Disbonding

De-icers act by one of two processes. One is by dissolving with a body of ice or snow and thus simply melting the mass of material from the top down. The second is by penetrating the main body of material and then dissolving a thin layer between the snow or ice and the pavement. The latter process breaks the ice/pavement bond, and is more efficient in terms of quantities of de-icer used and vehicle safety. Less de-icer is used because only a small mass of material need be melted, first in a vertical channel and then at the ice/pavement interface. It creates a safer driving surface because the surface is not covered with a layer of de-icer solution.

In practice, the two de-icing processes occur together and one criterion for comparison of de-icers is the relative occurrence of the preferred, bond breaking process over the less desirable, surface melting process. It is not possible to measure the relative occurrence in the field, but the dominant process can be inferred from qualitative changes in the snow or ice after the de-icer is applied.

The effectiveness of de-icing can be assessed by observing changes in the material on the road surface, over time. If the bond breaking process is dominant, the snow or ice will be cast from the road by vehicle tires or plowing to expose bare pavement which is wet with de-icer solution. If melting at the surface occurs and sufficient de-icer is applied, the snow or ice will gradually turn to slush and then to solution. Providing it does not re-freeze, the solution gradually drains or evaporates from the pavement, leaving a bare and dry surface. The rate at which the pavement dries depends on the relative humidity, precipitation, wind and sunlight, as well as on the chemistry of the de-icer.

Ice melting effectiveness was documented in the Owen Sound trials by mapping the road surface condition at pre-determined sites in the test sections (Figures 1 and 2), prior to applying material and at regular intervals of time thereafter. Weather and traffic conditions were also measured.

Table 2/ Road condition classification

I	Icy	hard and slippery
SP	Snow Packed	packed snow
SC	Snow Covered	loose snow
S	Slushy	wet slush
BW	Bare and Wet	liquid solution
BDP	Bare and Damp	partially wet appearance
BD	Bare and Dry	dry
R	Residue	sand or de-icer residue
F	Frost	frost crystals visible (early morning)

A standardized format was used to map the pavement conditions and record the weather conditions. Parameters included the type, thickness and lateral extent of snow, ice, or de-icer solution on the pavement; road surface temperature; and meteorological conditions. The road condition classification is shown in Table 2, and example recording sheets are included in Appendix B.

All measurements were undertaken manually during the 1989/90 trials, by personnel who were trained in data collection procedures and assigned exclusively to the data collection task while tests were in progress. Pavement temperatures were measured at the outer wheel track and the lane centre using a

hand-held temperature probe. Air temperature, wind speed and direction were also measured with hand-held instruments.

During the 1990/91 trials, several additions were made to the procedures and an automated data collection system was installed at one site. At all sites in the CMA section, thermocouples were installed in the pavement to measure road surface temperature, and thermometers were mounted on roadside posts to measure air temperature. The thermocouples were encased in silicone, installed in saw cuts 1 cm below the wearing surface, and covered with loop detector sealant, and were situated in the outer wheel track and the centre of the eastbound driving lane. In addition, the pavement was marked with painted lines, spaced at 30 cm intervals across both lanes, to assist in accurate mapping of the road surface conditions (Figure 6).

An automated data collection system was installed at Site 3 (Figure 2). Road weather data were recorded at 30-minute intervals and the road surface condition was recorded on videotape at 4-second intervals (Figure 7). The road weather data included pavement temperature, measured from 10 thermistors at 35 cm spacing across the eastbound lane; wind speed and direction measured at 4 metres above ground, at the base of the side slope (15.4 metres to the south of and 1.8 metres higher than the pavement centreline); air temperature; relative humidity; and total radiation.

The paint lines, imaged in the video system, provided a calibrated record of the rate of de-icing during every CMA application. A luminaire was installed at this site to allow night-time videotape recording.

Conditions in at least one site in the CMA test section were monitored manually during every storm or highway de-icing event. As well, de-icing was monitored in the salt section as time allowed. The maximum time interval between monitoring was 2 hours in 1989/90 and 15 minutes in 1990/91.

Hourly traffic volume in each direction was measured during the first test season using a microwave detector mounted on a hydro pole at Woodford sub-yard, the midpoint of the test area (Figure 1, Appendix C). Traffic data were collected from January 1 through April 4, 1990. Traffic volumes were estimated by the monitoring personnel at other times. In 1990/91, traffic was measured using an electromagnetic loop detector installed in the pavement surface at the same location (Appendix C). This system was operational throughout the test period.

Figure 6/ Pavement markings at test sites

Figure 7/ Videotape of road conditions, November 11, 1990 at 2:07 P.M.

3.7/ Other Characteristics

Other factors relevant to the performance of a de-icer were observed and documented by monitoring and MTO patrol personnel, and spreader or plow operators. These characteristics include:

- degree of disbondment of ice from the pavement;
- slipperiness;
- drying of pavement and sticking of blowing snow;
- persistence of de-icing action; and
- effect on vehicles.

4/ Analysis and Results

4.1/ Quantities Applied

Statistics summarizing the de-icer applications in the CMA and salt test sections are shown in Table 3. During the first test season from November 4, 1989 to April 4, 1990, CMA or CMA/sand mix was applied 181 times in the CMA test section. Data from the CMA and salt test sections in 1989/90 exclude eight events in which salt was applied in the CMA section and 17 events in which salt/sand mix was applied in the CMA test section. The reasons for use of salt in the CMA test section were:

- the storage facility had run out of CMA or CMA/sand mix;
- the spreader dedicated to CMA had mechanical problems;
- salt was deemed necessary to remove an icing condition; and
- due to spreader availability, salt/sand application permitted a faster response during critical icing conditions.

During the 1990/91 test season, from November 7, 1990 to April 15, 1991, CMA or CMA/sand was applied 221 times. No salt was used in the CMA section. Records for this season did not distinguish between full, spot or multiple applications during the same spreader call-out in the salt section; therefore, they were not included in the "Number of Applications" section of Table 3.

Information directly comparing the number of applications and quantities of CMA and salt used must be interpreted with care. First, direct comparison requires that traffic and weather conditions in the CMA and salt test sections were similar, and this was not always the case. Patrol and monitor personnel observed that weather conditions frequently differed over short distances within the test areas as a

result of snow streamers from Georgian Bay. A parametric analysis which accounts for differences in weather or traffic conditions between test sites is presented in Section 4.5.

Second, seasonal comparisons assume that the same number of storms were serviced using each chemical or sand/de-icer. For example, simple comparisons of the number of de-icer applications and total quantities applied, suggest that CMA was more effective, or remained effective longer than salt. However, the much greater quantity of sand used in the CMA section means that there were times when salt was effective but CMA was not, and sand had to be applied to provide traction only in the CMA section. Also, the data do not include several storms in which salt had to be applied in the CMA section to remove an icing condition. In summary, the seasonal application data suggest that CMA was less effective than salt.

Table 3/ Summary of material use

Number of Material Applications [1,2]	**1989/90**	**1990/91**
CMA	59	77
CMA / sand mix	122	142
salt	65	-
salt / sand mix	133	-
ratio CMA : salt	0.91	-
ratio CMA / sand : salt / sand	0.92	-
Mass Applied Per 2-lane km (kg) [1,3,4]		
CMA	18,750	14,615
CMA / sand mix	117,329	192,308
salt	18,048	29,771
salt / sand mix	99,095	108,153
ratio CMA : salt	1.04	0.49
ratio CMA / sand : salt / sand	1.18	1.78
ratio CMA / sand : CMA	6.2	13.1
ratio salt / sand : salt	5.5	3.6

1. *Excludes storms in which salt or salt/sand were applied in CMA section.*
2. *Excludes 'spot' applications.*
3. *Averaged over test section.*
4. *Includes 'spot' applications.*

\- *data not available.*

4.2/ Storage and Handling

Several mechanical problems were experienced with the storage and handling system during the first season of operation. The first problem was overload of the electrical motor during start-up of the auger to transfer material out of the storage bin into the spreader. This was rectified in two ways: first, the diameter of the auger flights which extended into the loading bin at the bottom end of the auger was reduced, thus reducing the loading rate. Second, the auger was run until it was completely empty before the motor was switched off.

The second problem was the escape of CMA dust from the end of the auger as the material was being loaded into the spreader truck (Figure 8). Installation of a flexible nozzle on the end of the loading auger, to confine the dust until it settled in the spreader bin, rectified the problem (Figure 4).

Figure 8/ Test of loading auger, 1989/90, showing CMA dust.

The presence of the dust raised concerns that the CMA pellets could be abraded by the augers. Samples were taken when the CMA was unloaded from the highway transport truck into the storage bin, and when it was loaded into the spreader truck, to determine whether attrition occurred in passing through the loading and unloading augers. Comparison of the size distributions of the two samples indicates that a small amount of attrition occurred (Appendix D).

The level indicating devices did not function consistently, because CMA pellets became packed into the mechanical actuating levers. This did not interfere significantly with operations as the level could be judged by looking through a trap door at the top of the bin. A dust mask was used as a precaution against inhaling CMA dust in the bin. An odour of acetic acid was evident inside the storage bin, and also inside the sand storage dome where CMA was mixed in the sand stockpile. CMA was observed to stick to the corrugated inside walls of the storage bin, but fell readily when the bin wall was struck.

Liquid CMA, used during 1990/91 only, was delivered in 205 litre steel drums, and pumped into a reservoir on the spreader truck as needed. Bacterial slime was observed floating on the liquid in the steel drums upon opening, after delivery from the supplier. This was anticipated due to metabolism of acetate by bacteria, and posed no operational problems.

CMA was mixed with winter sand to prevent stockpile freezing. A rate of 5% by mass was used in 1989/90 and 2% by mass in 1990/91. Both rates were effective in preventing freezing of the stockpile. In the 1989/90 test, CMA pellets in the stockpile became sticky or mushy and appeared to have absorbed moisture from the surrounding sand, which had become dry with time. This did not occur in the second year. As shown in Appendix F, the bulk moisture content of the stockpiles used in 1989/90 did not differ significantly during the winter season. It was not possible to measure changes in interstitial moisture surrounding individual sand grains.

4.3 / Application Experience

During both winters CMA was observed to stick to the sides of the spreader bin which, at times, prevented it from falling onto the spreader conveyor. This problem occurred whenever CMA was loaded into a wet spreader. The problem was solved partially by parking the spreader truck in a garage or sand storage dome, and by scraping and washing off any material remaining in the spreader bin immediately after use.

The CMA was spread by dropping it over a stationary or slowly rotating spinner to effect spreading across the road surface. Water splashing from the road caused the CMA to cake on the spinner to the extent that it had to be scraped and washed off between applications.

In the second year of trials, patrol workers noted that the CMA pellets did not spread evenly across the road surface but appeared to be moved by air currents under the spreader truck, onto the right lane. This was particularly evident during icy conditions. The spreader was adjusted so that the pellets dropped onto the forward side of the rotating spinner, and thus were thrown farther to the left lane.

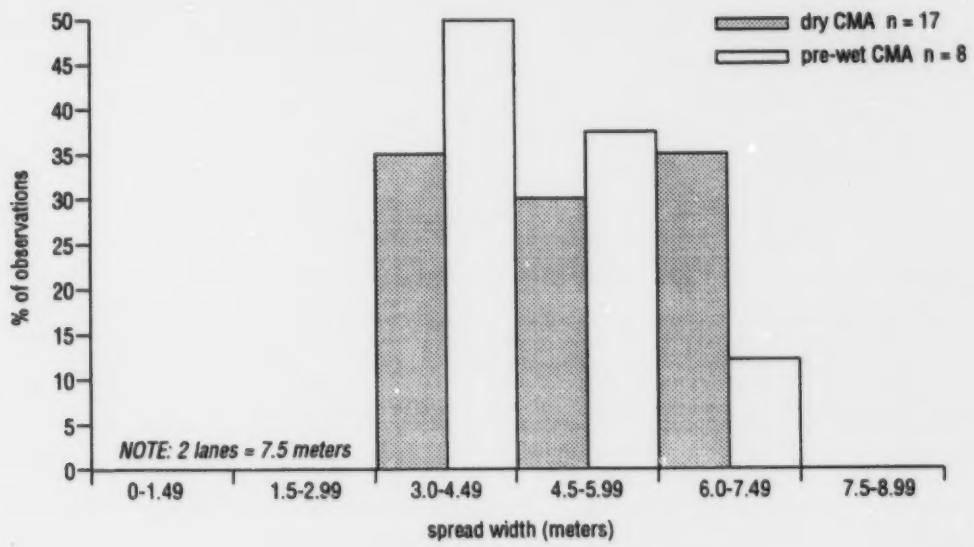


Figure 9/ Effect of pre-wetting on spread width of CMA

4.4/ Spread Width and Blow-off

CMA pellets were observed to bounce more than salt on hitting the pavement, unless the road was moist or snow covered. They were also blown off the road by wind, and by air currents from trucks following the spreader.

In eight tests, CMA pellets were pre-wet with a 25% CMA solution to determine whether a liquid coating would help the CMA adhere to the road surface. In very windy conditions, sand was spread on top of the CMA to hold it onto the road. This required a second pass of the spreader truck, 30 to 60 minutes after the CMA was applied.

The use of liquid spray improved the adhesion of CMA to the road surface. Figure 9 shows a histogram of spread width using dry and pre-wetted CMA under a variety of environmental conditions. Spread widths for dry CMA were distributed uniformly between 3.0 and 7.5 metres, extending across both lanes. Spread widths for pre-wetted CMA were more often in the range of 3.0 to 4.5 metres.

4.5/ Effectiveness of Ice Melting and Disbonding

4.5.1/ General Characteristics

The effectiveness of CMA at melting and disbonding ice was not compared with sodium chloride on a case-by-case basis, because road weather conditions in the CMA and salt test sections were not sufficiently similar to do so. However, it is useful to compare the de-icing processes observed for the two chemicals.

In the case of salt, one of two processes was observed, depending on road weather conditions. Under relatively warm temperatures and light snowfall conditions, salt created a solution with the snow almost immediately upon application, and the solution drained off the road. Under more severe conditions when a snowpack had formed on the pavement, salt was observed to penetrate the snowpack, usually within a period of 30 minutes, to disbond the snowpack from the pavement and facilitate plowing. This occurred at temperatures down to approximately -12°C.

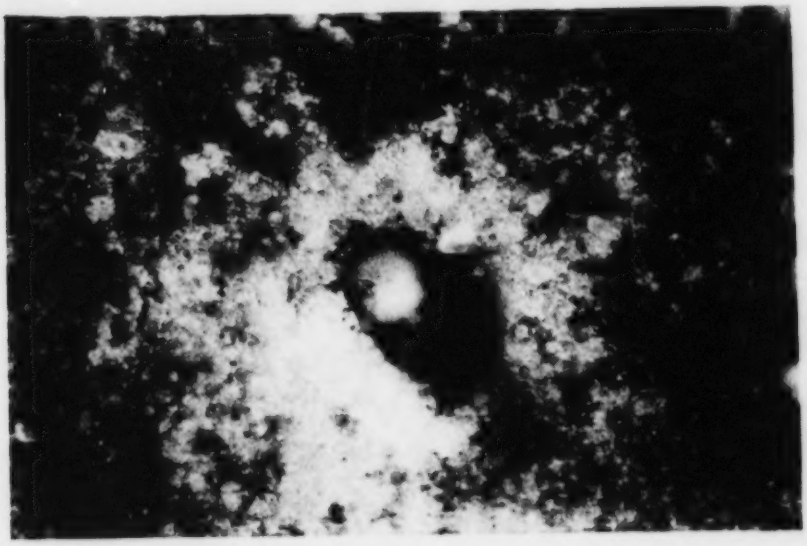


Figure 10/ CMA pellet penetrating thin snow cover

De-icing processes associated with CMA differed from those observed with salt. They were sensitive to precipitation, air temperature conditions, the type of material on the road, and traffic. Under relatively warm temperatures (above approximately -6°C) and light snow conditions with little traffic, CMA quickly penetrated the thin snowcover, but did not go into a solution with the surrounding snow once it had reached the pavement surface. Instead, it remained in solid form on the pavement within the original pit melted in the snow, as illustrated in Figure 10.

When CMA was applied on snowcover or snowpack, with light to moderate snowfall, air temperatures above -6°C, and traffic present, pellets in the wheel tracks dissolved to form a slush, but not a liquid. Tire action gradually pushed the slush off the wheel tracks onto the lane centre, the pavement edge and the centreline, where it formed ridges 1 to 5 cm high. The ridges had a slushy base and a dry crest composed of a mixture of snow, winter sand, slush and undissolved CMA pellets. Material within the ridge appeared to be dry, and CMA pellets remained for hours or days until traffic or rising temperatures enhanced the solution process. Slush in the wheel tracks and ridges outside the wheel tracks was plowed readily from the road surface. The slow change in pavement conditions typical of this de-icing scenario is illustrated in Figure 11.

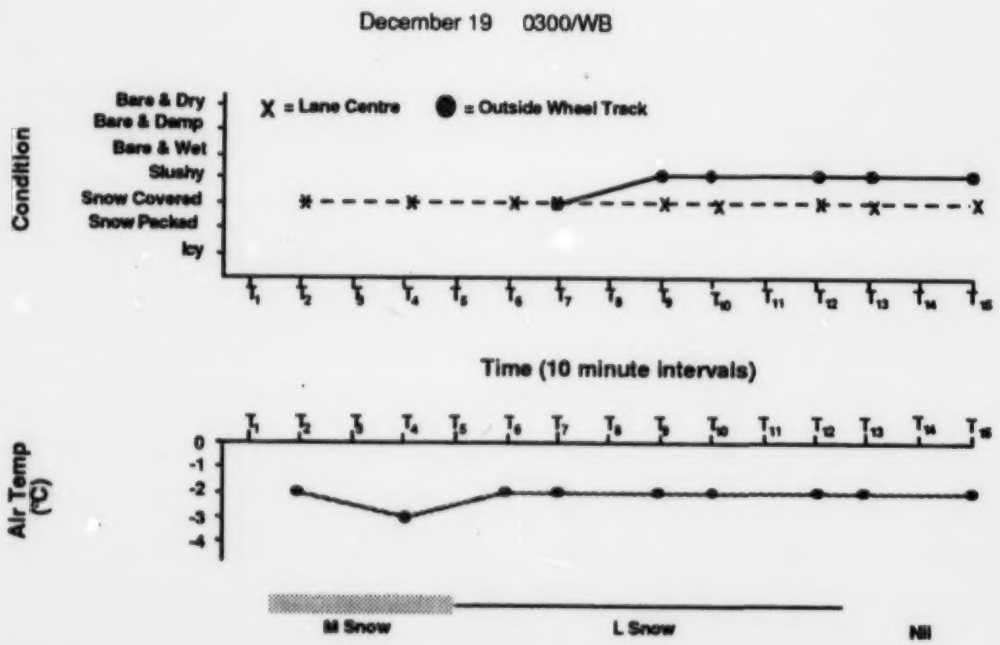


Figure 11/ Reaction of CMA at air temperature >-6°C, with light to moderate snow and moderate traffic

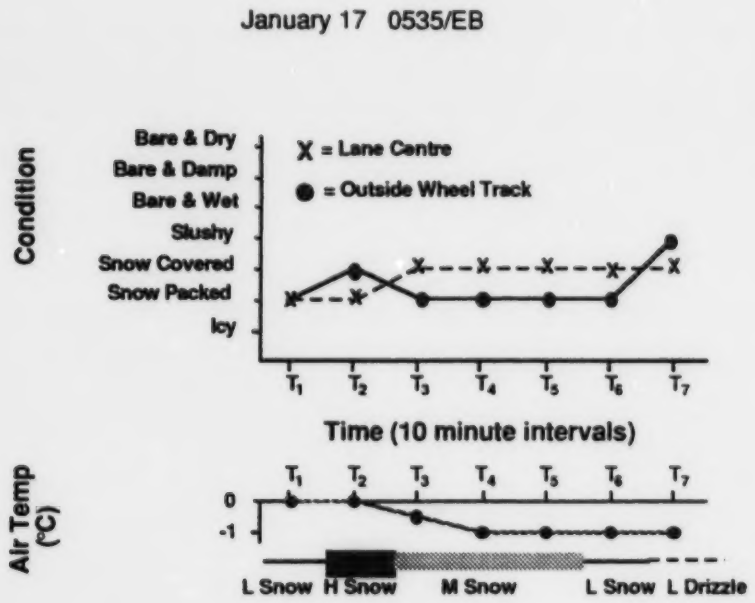


Figure 12/ Reaction of CMA at air temperature >-6°C, with light to heavy snow and light traffic

In warm temperatures and heavy snowfall, the CMA pellets did not dissolve quickly enough to melt the accumulating snow and they were covered by the snow. When the snow stopped falling, the CMA began to dissolve with it to form slush which was then plowed from the road. Deterioration of conditions during heavy snowfall is illustrated by the "Outside Wheel Track" condition in Figure 12.

At temperatures below -6°C and with traffic present, CMA dissolved very slowly with snow on the road to form a slush. Slush began to form after approximately 30 minutes, depending on traffic volume, and continued to form over a period of two hours or more. Again, CMA pellets remained undissolved outside the wheel tracks for hours or days after application.

The slush material yielded readily to vehicle tires and did not interfere with directional stability. Initially it reduced skid resistance to the point that sand had to be applied, in some instances, to provide sufficient traction for hill climbing. After a period of time the slush became sticky and vehicle traction was enhanced.

After the end of a storm and following plowing of the remaining slush and snow from the pavement surface, a moist residue of CMA remained on the pavement for several hours or days. The pavement had a shiny, damp appearance although liquid was not visible. Blowing snow was observed to stick more readily to such pavement than to dry pavement in the salt section. However, the snow did not

become bonded to the pavement and was readily plowed off. More frequent plowing was therefore necessary.

Early in the morning the CMA residue appeared as a shiny film, but was not noticeably more slippery than pavement sections without residue, in qualitative tests.

Pre-wetting the CMA pellets with a 25% solution of CMA in water increased the rate of reaction significantly. In several tests at temperatures above -6°C, the pre-wetted CMA dissolved snow in the wheel tracks at approximately the same rate as did salt. At colder temperatures, pre-wetted CMA dissolved more quickly than dry CMA, but much more slowly than salt.

4.5.2/ Ice Melting Effectiveness

The effectiveness of de-icing was quantified in 1989/90 by tabulating the frequency with which road surface conditions improved within a 2-hour time period. In 1990/91, a 30-minute criterion for effectiveness was used in addition to the 2-hour criterion. The 30-minute criterion corresponds approximately to results achieved with rock salt at temperatures above -12°C, and is the basis of MTO quality standards for clearing snow and ice from highways [1]. Thus, the criterion is an indirect method of comparing CMA with salt, and of determining whether Ministry Quality Standards can be met using CMA.

In both years, an effective application was defined as one in which the pavement condition (as defined in Table 2) improved by at least one category within the prescribed time period. It should be noted that the pavement condition classification was not identical in the first and second years of the trials. In the first year, condition refers to the predominant condition across the driving lane at the test site. In the second year, condition was mapped separately for the inner and outer wheel tracks, the lane centre, and the pavement edge zones of each lane. In the 1990/91 analyses which follow, "pavement condition" refers to the condition of the outer wheel track zone at the test site. The classifications for the two years are therefore not exactly the same, although they show comparable trends in the effectiveness of CMA.

Other qualifications of the analyses relate to initial condition, completeness of monitoring records and material applied. Data were excluded if the initial condition was bare and dry, bare and damp or bare and wet; if the frequency of monitoring was less than once in two hours (1989/90), or once in 15 minutes (1990/91); or if sand was applied during the monitoring period.

The duration of de-icing is defined as beginning at the time of material application, and ending at the observation just prior to plowing or to the next material application.

In all cases, CMA was applied only in conditions under which there would be a high expectation that rock salt would be effective. As shown in Table 4, using the 2-hour criterion for effectiveness, CMA was successful in 74% of the applications in 1989/90 and 80% of the applications in 1990/91 (excluding applications of pre-wetted CMA). Note that direct comparison of the two years' data is not possible because of the different methods of measuring effectiveness. These success rates are somewhat lower than the rate expected from salt under similar conditions (100%), especially considering that the 2-hour criterion is less stringent than the standard used by MTO when applying salt.

Table 4/ Success rate of CMA using two-hour criterion (% of applications successful)

	1989/90	1990/91
All Data	**74**	**80**
By Air Temperature (°C)		
≥ 4.9	100	100
- 5 to - 7.9	84	86
- 8 to - 10.9	44	80
≤ - 11	20	80
By Traffic Count (vph)		
0 - 39	61	88
40 - 79	80	100
80 - 119	82	91
≥ 120	100	87

Success is defined as an improvement in pavement condition by at least one category within two hours after application of CMA. Categories in 1989/90 refer to predominant condition of lane. Categories in 1990/91 refer to outside wheel track of lane.

Table 5/ Interaction of air temperature and traffic count on success rate of CMA using two-hour criterion, 1989/90 (% of applications successful)

	Temperature (°C)			
(vph)	≥ - 4.9	- 5 to - 7.9	- 8 to 10.9	≤ - 11
0 - 39	100	62	73	0
40 - 79	100	100	40	100
80 - 119	100	100	100	-
≥ 120	100	100	-	-

- ≤ 3 data points

Table 4 shows trends of decreasing effectiveness with decreasing air temperature, and increasing effectiveness with increasing traffic, and suggests that these variables act together to influence de-icing. This trend would be expected for any chemical de-icer. The interaction of temperature and traffic is illustrated in Table 5 which shows the de-icing success rate for combinations of these variables, using data from 1989/90.

Additional information on the influence of air temperature on effectiveness is shown in Figure 13. It illustrates the effectiveness of CMA acting on snowpack in 1989/90. All of the applications were successful at temperatures above -6°C, some were successful between -12 and -6°C, and none were successful below -12°C. In total, 44% of the applications on a snowpacked surface were successful, with 12% resulting in slight improvement to snowcovered condition, 7% moderate improvement to track bare, 3% to slushy and 22% to bare and wet.

A more detailed analysis of de-icer effectiveness was conducted using data from 1990/91, which were collected at shorter time intervals. These data were used to construct cumulative frequency curves of de-icing effectiveness. The curves show the relationship between elapsed time since de-icer application, and success rate or effectiveness of de-icing. The method used to construct a cumulative frequency curve is described in Appendix G.

The cumulative frequency of elapsed time between de-icer application and improvement in road condition is shown in Figure 14 for all CMA applications in 1990/91. When time is not limited, the success rate is 80% (curve for dry CMA). When elapsed time is limited to one hour the success rate is 68%, and when elapsed time is limited to 30 minutes the success rate is 50%. The 30-minute criterion provides the most useful basis for comparison with existing MTO maintenance standards using rock salt, because additional salting or plowing of disbonded ice is generally undertaken after about 30 minutes. The 30-minute success rate indicates that if CMA were substituted for salt in the MTO winter maintenance program, successful de-icing would be achieved in less than half of the conditions tested.

Additional information is presented in Figures 15 and 16. Figure 15 shows the influence of air temperature on the effectiveness and the rate of de-icing. As expected, the success rate increases with the duration of de-icing for all temperature ranges, and as temperature increases for most durations. Cases in which effectiveness does not increase with air temperature for elapsed times of less than 30 minutes suggest that other factors influence the initiation of de-icing immediately after the spreading of the material. Applying the 30-minute elapsed time criterion, the success rate in the temperature range above -8°C was 35 to 45% and in the range below -8°C was 10%. Considering the average time required for de-icing (ie, the 50th percentile of success) 40 minutes was required at 0 to -4.9°C, 50 minutes at -5 to 7°C and more than 140 minutes at temperatures below -8°C.

Figure 16 shows the influence of vehicle traffic on the effectiveness and the rate of de-icing. The success rate increases with the duration of de-icing for all traffic counts, and with increases in traffic count for most durations. As in Figure 15, data for elapsed times of less than 30 minutes do not follow the expected trend. Considering the 30-minute elapsed time criterion, the success rate was 30% for vehicle counts below 80 per hour and 45% for counts above 80. Considering the average time required for de-icing, 30 minutes were required at vehicle counts of 80 per hour or higher; 50 minutes were needed at 40 to 79 vehicles per hour: and 60 minutes were required at 39 or fewer vehicles per hour.

The results from the 1990/91 trials are in qualitative agreement with those from 1989/90.

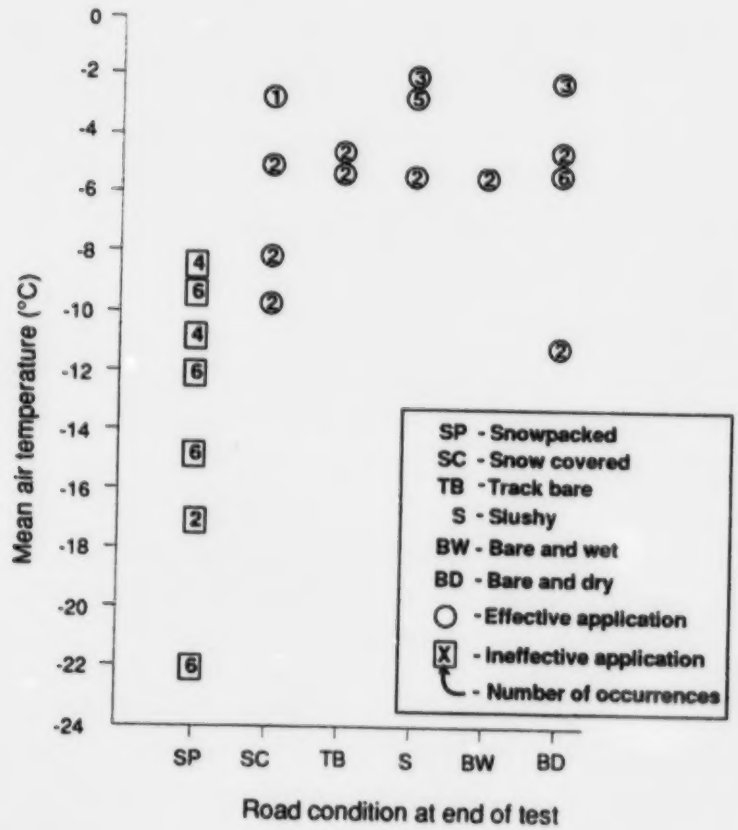


Figure 13/ Effectiveness of CMA in removing snowpacked condition, 1989/90

4.5.3/ Effect of Pre-wetting CMA

In 15 applications, CMA pellets were pre-wetted with a solution of liquid CMA to determine whether this would assist the de-icer in adhering to the pavement. Differences in de-icing action were observed during these applications, and an analysis was conducted to quantify the effects.

The "pre-wet" curve in Figure 14 shows the cumulative frequency of de-icing effectiveness using pre-wetted CMA. The effectiveness increased slightly with pre-wetting: approximately 50% of the applications of dry CMA were effective within 30 minutes, compared to 55% for the pre-wetted applications.

The dry and pre-wet applications occurred under a variety of road weather conditions which were not necessarily comparable. Pre-wetting was usually carried out under dry, cold, snow-packed conditions which are expected to reduce the effectiveness of a de-icer. Pre-wetted CMA can therefore be expected to perform better than is indicated in Figure 14, when compared with dry CMA under similar conditions.

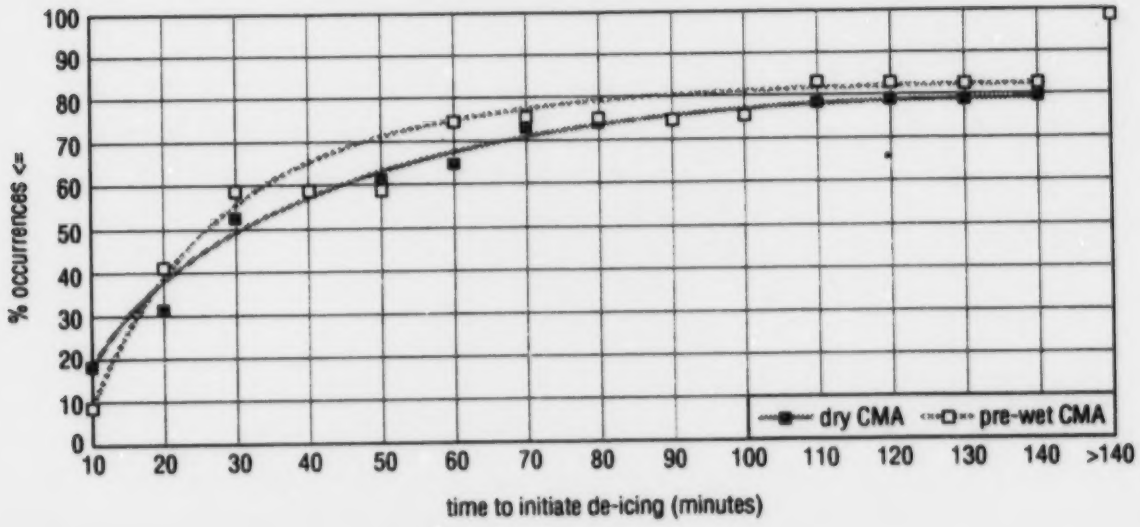


Figure 14/ Effectiveness of dry and pre-wet CMA, 1990/91

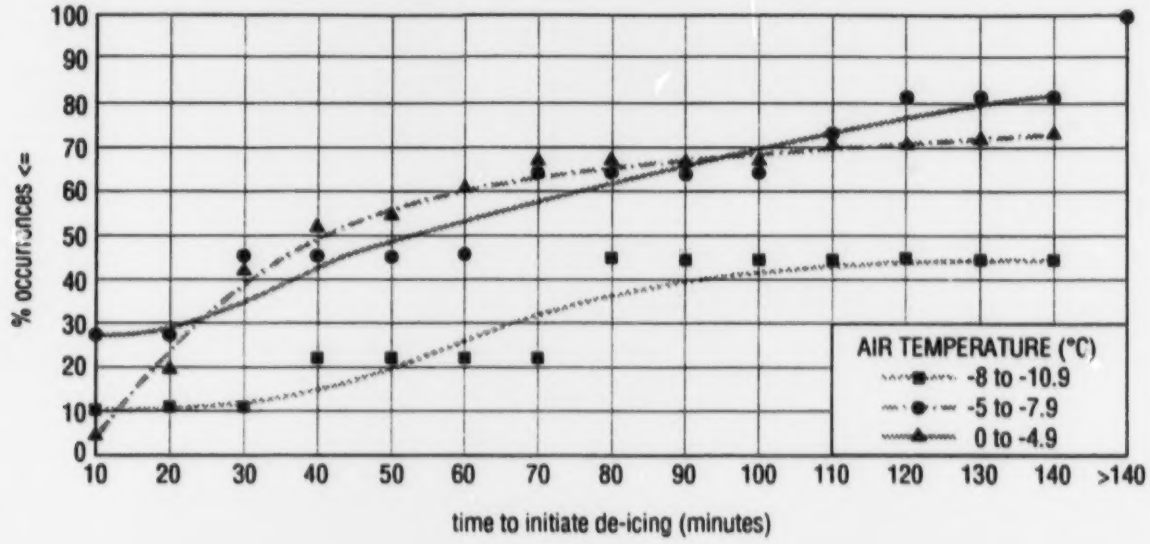


Figure 15/ Effectiveness of dry CMA by air temperature, 1990/91

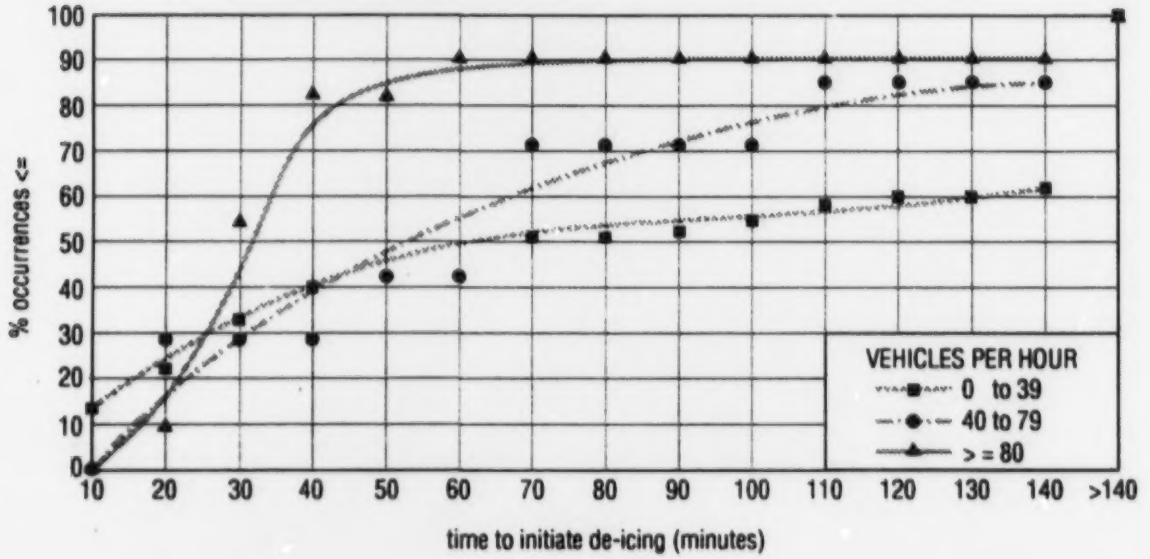


Figure 16/ Effectiveness of dry CMA by traffic count, 1990/91

4.6/ Other Characteristics

4.6.1/ Drying of Pavement

Previous studies suggested that CMA dries very slowly after reacting with snow or ice on the pavement [4]. This could have both desirable and adverse effects on driving conditions. A desirable effect is the initiation of de-icing during subsequent storms, which might prevent bonding of packed snow or ice to the pavement and reduce the total quantity of CMA needed. Adverse effects include adhesion of blowing snow to the pavement, and reduction of skid resistance due to a liquid film. Both adhesion of blowing snow and initiation of de-icing (anti-icing) were observed in this study.

Pavement drying time after application of CMA was documented using video records from Station 3 (see Figure 2) during the 1990/91 trials. The elapsed time from plowing of disbonded snow from the road until the pavement appeared to be dry was measured from the videotapes. A statistical comparison was not possible because rain or snow maintained a wet pavement in some samples, while in others a second snowfall occurred and de-icer was re-applied before the pavement dried. However, undisturbed drying times were typically several days. Comparative data were not collected in the salt section, but experience shows salt to dry typically within a day.

4.6.2/ Effect on Vehicles

Visual comparisons were made of the CMA and salt spreaders used during the trials, to observe corrosion of the machinery. No corrosion was visible on the CMA spreaders after either season of operation, while corrosion was evident on the salt spreaders.

A transparent, sticky film was observed to accumulate on monitor vehicles which were used primarily within the CMA test section. The film was difficult to wash off with soap and water.

A small number of reports were received concerning vehicles which regularly travelled the CMA test section, having unusually squeaky door hinges and underbody moving parts. This was also noted on the vehicle used by monitors.

No other environmental effects were included in the test plan, reported or observed.

5/ Conclusions and Recommendations

5.1/ Conclusions

The effectiveness of CMA as a highway de-icer has been studied over four winter seasons by MTO. Trials near Beamsville showed that it has effectiveness similar to salt under freeway traffic conditions, when temperatures are in the 0 to -5°C range and snow is light.

Trials near Owen Sound showed that the effectiveness of CMA decreases noticeably when traffic is light, temperatures are below -5°C and there is moderate snowfall or heavy drifting. Such conditions are typical of rural highways in Ontario.

In the Owen Sound trials, maintenance quality standards which are typically achieved using salt, were achieved only 50% of the time when CMA was used instead of salt. If the standards were revised to permit a one-hour period for the de-icer to act before the road was plowed, the rate of effectiveness would have been 68%, and for a two-hour period the rate would have been 74 to 80%. These rates could be increased by approximately 10% if the CMA were pre-wetted.

CMA can be an effective replacement for salt under a limited range of conditions. However, its adoption as a replacement for road salt would result in reductions in the level of service for snow and ice removal currently provided by MTO, even if the de-icer was applied at significantly higher rates than those used for salt.

5.2/ Recommendations for Further Research

It is recommended that further research be conducted into the effect on levels of service, of a province-wide switch to CMA as the standard highway de-icer. This could be undertaken by modelling the levels of service in snow and ice control at a few patrol yards selected to be representative of a range of weather and traffic conditions.

The levels of service model should be linked to models of vehicle mobility and accident risk. This will permit the costs and benefits of a switch to CMA to be estimated, from the perspectives of the Ministry and the provincial economy.

References

[1] MTO, "Operating Instructions; Winter Maintenance Standards", Series M-700, Vol. 4; Maintenance Manual, Highway Engineering Division, Ontario Ministry of Transportation, 1981.

[2] Dunn, S.A., and R.U. Schenk, "Alternative Highway De-icing Chemicals", Report No. FHWA-RD-79-109, U.S. Department of Transportation, Federal Highway Administration, 1980.

[3] Manning, D.G., and L.W. Crowder, "Comparative Field Study of the Operational Characteristics of Calcium Magnesium Acetate and Rock Salt", *Transportation Research Record* 1246, Transportation Research Board, U.S. National Research Council 1989, pp 18-26.

[4] Perchanok, M., D.G. Manning and J.J. Armstrong, *Highway De-icers: Standards, Practice and Research in the Province of Ontario.* R&D Report MAT-91-13, Ontario Ministry of Transportation, Toronto, 1991.

[5] Transportation Research Board, "Highway De-icing: Comparing Salt and Calcium Magnesium Acetate"; Special Report 235, Transportation Research Board, M.S. National Research Council, Washington, 1992.

[6] Brown, D.M., G.A. McKay and L.J. Chapman, "The Climate of Southern Ontario", Climatological Studies Number 5, Atmospheric Environment Service, Environment Canada, Toronto, 1980.

[7] Environment Canada, "Canadian Climate Normals, 1951-1980; Temperature and Precipitation, Ontario", Atmospheric Environment Service, Environment Canada, Toronto, 1980.

[8] Environment Canada, "Canadian Climate Normals, 1951-1980; Volume 9, Days With Blowing Snow", Atmospheric Environment Service, Environment Canada, Toronto, 1984.

Appendix A/ Material Application and Plow Operation Data Sheets (Examples)

CMA WINTER MAINTENANCE PLOWING REPORT

DATE	WESTBOUND ARR. TIME STATION 1	WESTBOUND ARR. TIME STATION 2	WESTBOUND ARR. TIME STATION 3	EASTBOUND ARR. TIME STATION 3	EASTBOUND ARR. TIME STATION 2	EASTBOUND ARR. TIME STATION 1
NOV 5-90						
NOV 11	2:16 PM	2:19 PM	2:20:23 PM	2:40:37 PM	2:42 PM	2:45 PM
NOV 11	3:59 PM	4:02 PM	4:05 PM	4:27:13 PM	4:28 PM	4:31 PM
NOV. 11	5:29 PM	5:32 PM	5:34 PM	5:47:01 PM	5:48 PM	5:51 PM
NOV. 11	7:44 PM	7:47 PM	7:48:46 PM	8:00:10 PM	8:01 PM	8:04 PM
NOV 11.	10:05 PM	10:08 PM	10:09 PM	10:12:07 PM	10:13 PM	10:16 PM

CMA WINTER MAINTENANCE PLOWING REPORT

7:08:31 PM WB 7:26:17 EB

DEC 15

DATE ↑	WESTBOUND ARR. TIME STATION 1	WESTBOUND ARR. TIME STATION 2	WESTBOUND ARR. TIME STATION 3	EASTBOUND ARR. TIME STATION 3	EASTBOUND ARR. TIME STATION 2	EASTBOUND ARR. TIME STATION 1
DEC 15	8.32 PM	8.35 PM	8.36 PM	8.54 PM	9.01 PM	9.04 PM
DEC 16	9:12 PM	9.15 PM	9.16 PM	9.30 PM	9.31 PM	9.34 PM
DEC 19	5:30 AM	5:33 AM	5:35 AM	5:54 AM	5:56 AM	5:58 AM
DEC 19	9:06 AM	9:09 AM	9:10 AM	9:34 AM	9:35 AM	9:38 AM.
DEC-23	3:18 AM	3:21 AM	3:22 AM	3:43 AM	3:45 AM	3:48 AM
"	4:35 AM	4:37 AM	4:38 AM	4:53 AM	4:54 AM	4:57 AM
"	6:54 AM	7:57 AM	6:58 AM	7:18 AM	7:20 AM	7:22 AM
DEC. 23			4:20:52 PM	4:34:10 PM		
DEC 24	1.24 AM	1:27 AM	1.28 AM	1:48 AM	1:49 AM	1:52 AM
	2:36 AM	2:39 AM	2:40 AM	3:24 AM	3:05 AM	3:08 AM
	5:00 AM	5:03 AM	5:05 AM	5:25 AM	5:27 AM	5:30 AM
	6:31 AM	6:34 AM	6:36 AM	6:55 AM	6:57 AM	6:59 AM
	1:14 PM	1:17 PM	1:18 PM	1:51 PM	1:53 PM	1:56 PM
	3:09 PM	3:12 PM	3:13 PM	3:43 PM	3:44 PM	3:47 PM
	5:54 PM	5:57 PM	5:59 PM	6:22 PM	6:24 PM	10:25 PM
	8:55 PM	8:56 PM	8:57 PM	7:16 PM	9:18 PM	9:20 PM
DEC 25						
	3:48 AM	3:51 AM	3:52 AM	4:16 AM	4:12 AM	4:15 AM
DEC 25	10:38 PM	8:41 PM	8:43 PM	9:09 PM	4:10 PM	4:13 PM
	10:05 PM	10:06 PM	10:08 PM	10:28 PM	10:30 PM	10:33 PM
			10:07:32	10:25:06		

CMA WINTER MAINTENANCE APPLICATION REPORT

DATE	ARR. TIME STATION 1	ARR. TIME STATION 2	ARR. TIME STATION 3	CONT. APPLIC.	SPOTTED APPLIC.	TYPE OF APPLICATION CMA	SAND	MIX	LIQUID CMA	APPLIC. RATE	COMMENTS
Nov 12-90			9:30 PM	✓		✓				195	
Nov. 12			10:36:21 PM	✓			✓			570	
NOV. 24			1:52 AM	✓		✓				195	FOGGY VISION SCRIN
Nov 24			11:53:09 PM	✓		✓				195	
Nov 29	5:21 PM	5:30 PM			✓	✓				195	
Nov 29	7:20 PM		7:28 PM		✓		✓			570	
Dec 3			9:57:21 AM	✓			✓			570	
Dec 3			10:22 AM		✓		✓			570	
Dec 3			12:31 PM		✓		✓			570	
Dec 3			3:00:09 PM	✓			✓			570	
Dec 3			3:17 PM		✓		✓			570	
Dec 3											

CNA WINTER MAINTENANCE APPLICATION REPORT

DATE	ARR. TIME STATION 1	ARR. TIME STATION 2	ARR. TIME STATION 3	CONT. APPLIC.	SPOTTED APPLIC.	TYPE OF APPLICATION CNA	SAND	MIX	LIQUID CNA	APPLIC. RATE	COMMENTS Time for Liquid CNA
Feb. 14	2:20 PM	2:25 PM	2:29 PM	✓			✓		✓	570	24 min. & 34 sec. 30 Km/h
Feb. 14	3:49 PM	3:53 PM	3:56 PM	✓			✓			570	
Feb. 14	5:49 PM	5:53 PM	5:57 PM	✓			✓			570	
Feb. 14	7:19 PM	7:23 PM	7:27 PM	✓			✓			570	
Feb. 14	9:20 PM	9:24 PM	9:28 PM	✓			✓			570	
Feb. 15	5:24 AM	5:28 AM	5:32 AM	✓			✓			570	
Feb. 15	7:19 AM	7:23 AM	7:24 AM	✓			✓			570	
Feb. 15	3:19 PM	3:27 PM	3:24 PM		✓		✓			570	
Feb. 15	6:24 PM	6:28 PM	6:31 PM		✓		✓			570	
Feb. 16	6:26 AM	6:30 AM	6:34 AM		✓		✓			570	
Feb. 16	1:24 PM	1:28 PM	1:31 PM	✓			✓			570	
Feb. 16	3:49 PM	3:53 PM	3:56 PM	✓			✓			570	
Feb 17	6:14 AM	6:18 AM	6:27 AM	✓		✓			✓	221	2H min & 45 sec. 30 km/h
Feb 17	8:10 AM	8:14 AM	8:18 AM	✓			✓			570	
Feb. 18	8:30 PM	8:34 PM	8:38 PM	✓		✓				221	
Feb. 18	10:56 PM	11:00 AM	11:04 PM	✓		✓				221	
Feb 19	1:36 AM	1:38 AM	1:46 AM	✓		✓				221	
Feb. 19	3:48 AM	3:52 AM	—		✓	✓				125	

Appendix B/ Monitor Sheets (Examples)

Attachment 4

FORM B - CMA WINTER MAINTENANCE TEST REPORT (CMA/SALT CONTROL TEST SECTION)

STORM #7

DATE OF APPLICATION Nov. 28/89

STARTING APPLICATION TIME 07:40

TYPE OF DEICER: SALT ☑ SAND/SALT MIX ☑

TIME OF PLOWING: W.B. 08:15 E.B. 09:06

EVALUATION PARAMETERS	MONITORING STATION LOCATIONS 1) "G. SCHWLLINGER" MAILBOX, WB HWY 26 NORTH SIDE, 2.2 KM EAST OF SYDENHAM CONCESSION 6		2) "G. SNIDER" MAILBOX, WB HWY 26 NORTH SIDE, 3.4 KM EAST OF SYDENHAM CONCESSION 6		3) "WOODFORD" WB TOWN SIGN, HWY 26, NORTH SIDE, 7.2 KM EAST OF SYDENHAM CONCESSION 6	
	E.B.L.	W.B.L.	E.B.L.	W.B.L.	E.B.L.	W.B.L.
TIME OF OBSERVATION	830 hrs		836 hrs		845 hrs	
AIR TEMPERATURE °C	-2°		-2°		-3°	
PAVEMENT EDGE TEMP. °C	-1.6		-1.9		-1.7	
WIND DIRECTION	N		N		N	
VELOCITY AVG K/HR	4		14			
SKY CONDITIONS						
TENTHS CLOUD COVER (0-10)	10		10		10	
SUNNY						
FOG						
RAIN (H,M,L)	—					
ICE PELLETS (H,M,L)						
SNOW (H,M,L)	LT		LT		LT	
ROADWAY SURFACE CONDITIONS						
BARE & DRY						
BARE & WET	✓					
TRACK BARE		✓		✓		
SLUSHY/DEPTH (MM)		2MM			✓	
SNOW COVERED/DEPTH (MM)			✓5MM			✓
SNOW PACKED/DEPTH (MM)					2 CM	2 CM
ICY/DEPTH (MM)						
RESIDUE						
TRAFFIC L,M,H	L	L	L M	M	M	M

QUANTITY OF DEICER APPLIED - SALT 1 tonne SAND/SALT MIX 5 tonnes

COMMENTS MET SNIDER 829 AM W/B
OUTSIDE TRACKS LT SNOW EV'D & SLIPPERY
LT. GRD DRIFTING, STN 2 - & W/D TRACK SLIPPERY

SIGNATURE OF MONITOR D. R. Bowen

CMA TRIALS FIELD SHEET

Station #: 2

Date: Jan 19/91 Time (24 h): 6:15

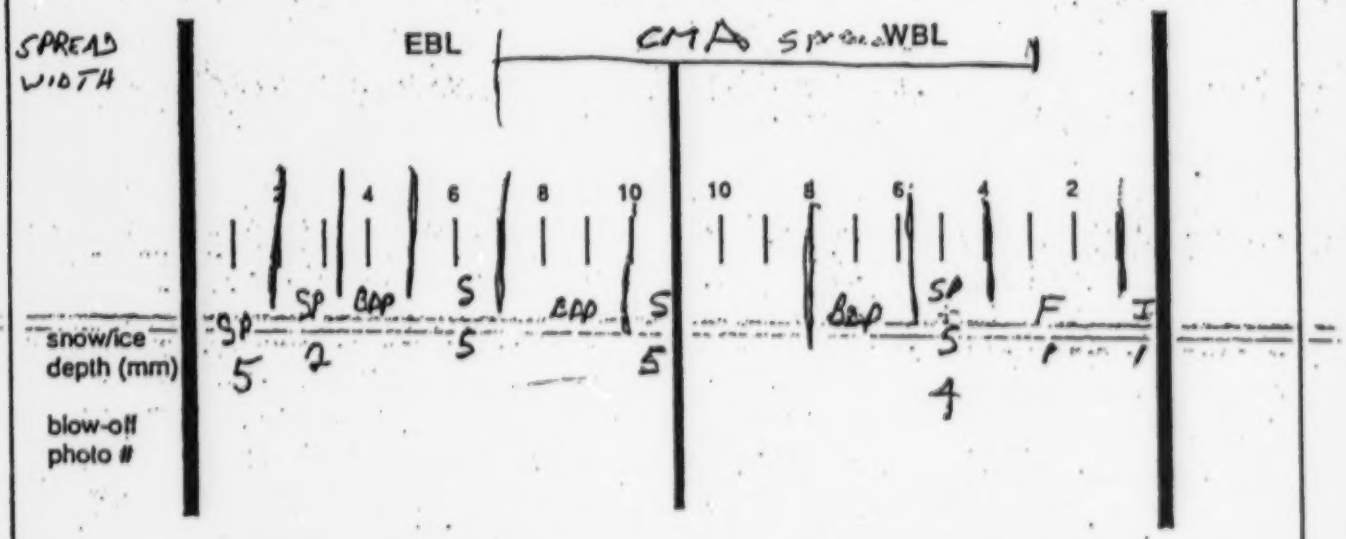
Air Temperature: -1 °C

Wind Speed: 18 km/h Direction (from): S-W

Cloud cover/Precipitation: 10/10

Pavement Temperature: -2.8 edge -2.1 wheel track

BD bare and dry
BW bare and wet
I icy
S slushy
SC snow covered
SP snow packed
R residue
BDP bare and damp
F frost



Last Plow Pass: _____ EBL _____ WBL

Last Spreader Pass: _____ EBL 6:14 WBL

Material Spread: (CMA) CMA/sand Other _____ Rate: 225

(Liquid Spray Rate:) ✓

Comments: Delay in Applying CMA

Observer: B. D

90/10/24

Appendix C/ Traffic Counter Specifications

1989/90

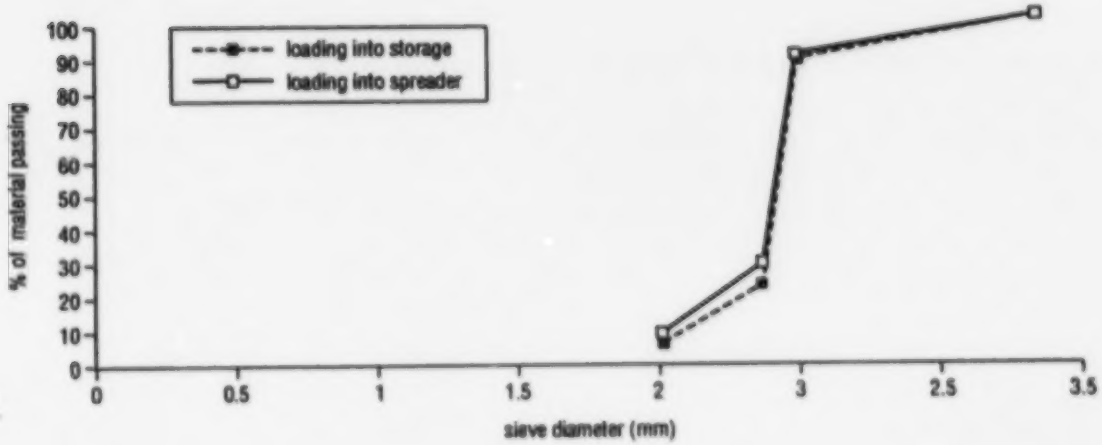
Model:	Microwave Sensors TC 20
Supplier:	Fortran Systems Ltd.
Frequency:	10.525 GH_z
Response Time:	165 ms
Recorder:	Model 170

1990/91

Model:	TWU14 gauge copper wire loop
Recorder:	StreeterAmet 141 traffic counter

Both systems supplied by Traffic Development and Analysis Section, Highway Operation and Maintenance Division, MTO.

Appendix D/ Size Distribution of CMA Before and After Storage



Appendix E/ Moisture Content of Winter Sand

Bulk Moisture Content of Winter Sand Used in CMA Trials

Average Bulk Moisture Content (% by Mass)

Date Sampled	Date Mixed	
	October 1990	February 1991
October 10	7.5	–
December 6	7.1	–
February 7	6.6	4.8
June 3	5.7	4.7

F/ Derivation of Cumulative Frequency Curve (Sample)

Minutes Since De-icer Application	Number of Cases in Which De-icing Begins	Cumulative Number of Cases	Cumulative %
0 - 10	21	21	18.3
11 - 20	15	36	31.3
21 - 30	24	60	52.2
31 - 40	8	68	59.1
41 - 50	3	71	61.7
51 - 60	4	75	65.2
>140		115	100.0

Example: In 52.2% of the cases studied, the de-icer began working within 30 minutes of application.